A Comparison of Fijian Forms of *Conus coronatus* and *Conus aristophanes*

BY

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(4 Text figures)

INTRODUCTION

The species known as *Conus coronatus* Gmelin, 1791 and *C. aristophanes* Sowerby, 1857 are common in Fiji. However, differentiating one from the other can be difficult.

Cernohorsky (1964) presents criteria for separating these two species. They are listed in Table 1. While these criteria are more definitive than others that have been published, and while they are generally satisfactory, they do not always permit identification of individual Fijian specimens. Not infrequently, a shell may be classified as *Conus coronatus* by some of the Cernohorsky criteria, but as *C. aristophanes* by others. It was difficulty in using these criteria that prompted the present study.

Specimens tentatively identified as *Conus coronatus* and *C. aristophanes* were collected in Fiji. Living animals were observed in their native habitat and in a home aquarium. The cleaned shells were then examined with the intent of elaborating on the criteria suggested by Cernohorsky and of exploring and defining additional characteristics that might be useful in discriminating between these two closely related species.

Upon gross examination, live animals of *Conus coronatus* could not be distinguished from those of *C. aristophanes*. Except for pale crawling surfaces and a bright touch of color at the tip of the siphons, the visible fleshy parts of both species were a translucent grayish white to tan dusted to varying degrees with small, irregular points of reddish purple to black pigment. The tip of the siphons varied from a pale red or orange in lighter colored individuals to a deep purplish-red in darker specimens. Variations in the degree of pigmentation were striking within both species. Attempts to distinguish between the two on the basis of color, pattern or form of the live animal were unsuccessful.

Table 1

Descriptive criteria for distinguishing between *Conus coronatus* and *Conus aristophanes* as given by Cernohorsky (1964).

	Conus coronatus	*Conus aristophanes*
1. Shape	ventricose	conical
Greatest width	below shoulder	at shoulder
Aperture	wide, flaring	narrow
2. Spire height	elevated	depressed
3. Spiral ridges	5 to 7, fine	1 or 2, coarse
4. Coronations	sharply cut, rarely obsolete	nodulose, often obsolete
5. Pattern:		
Blotches	present, brown	absent
Waist/shoulder bands	(not stated)	present
6. Basal ridges	strong, interrupted	strong, continuous

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Attention to habitat proved more revealing. Although the two species occasionally are found together on the main barrier reef, *Conus coronatus* seems to prefer a harder substrate, clearer water and a higher energy environment. It frequently is found just behind the reef's edge in heavily washed pockets or stretches of coarse sand. Only occasional specimens of *C. aristophanes* are found amongst the *C. coronatus* in such a habitat. On the other hand, *C. aristophanes* generally is found farther back on the reef in broad stretches of finer sand or mud that are protected from the pounding sea. At this kind of site, most specimens found were *C. aristophanes*.

The preference of *Conus aristophanes* for quieter water and finer sand or mud was observed at numerous locations along the southern Viti Levu coast. Mudflats extending from the mangroves out into the lagoon were often found to be populated by pure colonies of *C. aristophanes*. Live *C. coronatus* were never collected from this type of environment.

Details of the study of conchological features are presented below.

MATERIALS

A series of 50 specimens tentatively identified as *Conus coronatus*, and a second series of 50 tentatively identified as *C. aristophanes* were selected for conchological study. These were designated as the C-Group and the A-Group, respectively. Preliminary identifications were based on the criteria given by Cernohorsky (1964) with particular attention given to shape, the number of spiral striae and color. Although Cernohorsky did not list color as a criterion, he did note that the color of the body whorl of *C. coronatus* was fawn or pale brown while that of *C. aristophanes* was gray to greenish gray, and such seemed to be a reasonably constant characteristic. After gaining familiarity with these two species, assignment to the C-Group or A-Group was reasonably certain for about 90% of the specimens, but little more than a guess in other instances.

Specimens were selected from several localities to help lessen the possibility of undue influence by a peculiarity in any one colony. Members of the C-Group were from various reef locations around Suva and from the island of Nayau which lies in the Lau Group 240 km to the east of Viti Levu. Specimens in the A-Group were from the reefs around Suva and from Suva Point. The latter is a rather polluted rocky mudflat with few weeds and little coral. It is next to shore and immediately adjacent to the city of Suva. An extensive pure colony of *Conus aristophanes* lives there.

Only mature shells, or reasonably mature shells 20 mm or more in length, were accepted into the two study Groups. Only shells in good condition were selected for inclusion. No shell eroded to the extent that a potentially useful conchological character might be obscured was admitted into either group.

METHODS

Cleaned shells were examined grossly and with the aid of a hand-lens. Measurements were made with the aid of calipers modified by "rhinoplasty" as per Kohn & Riggs (1975).

Numerous differences between shells of the C-Group and the A-Group were apparent, but not a single feature could be called exclusive to either Group. Rather, it was observed that a characteristic would be more or less frequent in one Group than in the other.

When a character was perceived to be common in one Group but rare in the other, it was carefully defined with reference to typical specimens from the two Groups. Then each of the 100 shells was classified individually by that definition. In this way, each specimen was designated as belonging to the C-Group or the A-Group on the basis of that one characteristic. Assuming the original placement of shells was correct, or nearly correct, the number of shells mistakenly assigned to the wrong Group gave a measure of the number of errors generated by that definition. In no case was a defined character deemed acceptable as a criterion for distinguishing between Fijian *Conus coronatus* and *C. aristophanes* unless fewer than 5% of the shells were misassigned when applying it.

In the case of every definition posed, some shells were atypical. Either they could not be evaluated (*e.g.*, blotch color when there was no blotch), or they were midway between the more typical members of the two Groups. Such shells could not be clearly identified as belonging to either to the C-Group or the A-Group. To accommodate these specimens, a third, "Indeterminate," category was established for each definition. A large percentage of indeterminate specimens detracted from the usefulness of a criterion. Hence, any character which could not be evaluated with certainty in 50% or more of the specimens was not considered useful enough to pursue further.

RESULTS

Acceptable Criteria

Of the various conchological characters examined during this study, 7 were found to be highly specific. These were characters which, when they could be evaluated, identified a specimen in hand as either a member of the C-Group or the A-Group with a greater than 95% certainty. That is, using any one of these as a criterion, less than one evaluated *Conus coronatus* in 20 was misidentified as *C. aristophanes,* or vice versa. The 7 strong 95%-criteria are presented below. Results are summarized in **Table 2.**

This criterion, essentially the same as Number 1 of Cernohorsky, was often difficult to apply to a shell in isolation. However, comparing the shell in silhouette with specimens of typical shape (see Figure 1) nearly always permitted identification. Of the 95 shells which could be evaluated, 93 were correctly identified. Upon gaining some familiarity with shape as criterion, it was one of the most accurate means for distinguishing between Fijian forms of *Conus coronatus* and *C. aristophanes.*

2. Width

Conus coronatus: Broad with ratio of width to height of body whorl equal to 0.87 or more.

Table 2

Data establishing strong (95%) criteria for distinguishing between Fijian *Conus coronatus* and *Conus aristophanes* (see text).
The "+" column gives the number of specimens identified as *Conus coronatus* by the listed character.
The "−" column gives the number of specimens identified as *Conus aristophanes.*
The "0" column shows indeterminate specimens.

Conchological character	C-Group[1]			A-Group[2]		
	+	0	−	+	0	−
1. Shape	47	2	1	1	2	46
2. Width	48	0	2	2	4	43
3. Spire height	28	21	1	1	21	27
4. Spiral striae	48	2	0	1	5	43
5. Blotch color	43	7	0	1	14	34
6. Pits	39	10	1	1	9	39
7. Line count	30	19	1	1	26	22

[1]Group includes one specimen ultimately scored as *Conus aristophanes.* This specimen contributes three of the six "−" scores.
[2]Group contains 49 specimens rather than the original 50. One shell, a *Conus coronatus* mistakenly included in the Group, has been omitted.

1. Shape

Conus coronatus: Inflated conical with sides of body whorl uniformly convex in outline from shoulder to angular constriction near anterior tip. Sharply angular at shoulder with coronation generally pointing slightly inward. Maximum diameter below shoulder. Aperture wide and flaring.

Conus aristophanes: Conical with sides of body whorl slightly convex, flattened or nearly straight. Slightly rounded at shoulder with coronations vertically oriented. Maximum diameter usually at or near shoulder. Aperture narrow and straight.

Indeterminate: Shape intermediate between above (4% of specimens in present series).

Conus aristophanes: Narrow with ratio of width to height of body whorl equal to 0.84 or less.

Indeterminate: 0.85 or 0.86 (4%).

The width of each specimen was measured at its broadest diameter. The height of the body whorl was measured from the most anterior tip to the base of the first and second coronations at the shoulder in a line parallel to the axis of the shell's greatest length. This height represented the vertical projection of the lateral aspect of the body whorl and excluded the posterior portion of the last whorl. The latter was taken as spire.

The width/height ratios within the C-Group varied from 0.82 to 0.96. Only 2 shells had a ratio of less than 0.85. Ratios within the A-Group varied from 0.77 to 0.88

with 2 specimens above 0.86. The C-Group averaged 0.90 (standard deviation: ±0.025); the A-Group averaged 0.82 (s. d.: ±0.02).

Considering the normal range of typical *Conus coronatus* as 0.85 to 0.95, and of typical *C. aristophanes* as 0.78 to 0.86 (average ±2 s. d. units), ratios of 0.85 and 0.86 were common to both. These ratios, where the ranges overlapped, were designated as indeterminate.

The relative width of a specimen was not readily discernable by simple visual inspection. The eye had difficulty ignoring shape and spire and distinguishing between the lower limits of "broad" and the upper limits of "narrow." Careful measurements with modified calipers were required for correct assessment by this criterion.

3. Spire Height

Conus coronatus: Elevated spire with ratio of height of spire to height of body whorl equal to 0.39 or more.

Conus aristophanes: Relatively low spire with ratio of height of spire to height of body whorl equal to 0.30 or less.

Indeterminate: 0.31 to 0.38 (42%).

This criterion is a quantified version of the Cernohorsky criterion Number 2 in Table 1. The height of the body whorl was measured as described above. The height of the spire of each specimen was determined by subtracting the height of the body whorl from overall length.

Spire height/body height ratios within the C-Group varied from 0.30 to 0.46 with an average of 0.39 (s. d.: ± 0.04). Only one shell had a ratio less than 0.32. Within the A-Group, ratios varied from 0.18 to 0.42 with an average of 0.29 (s. d.: ± 0.045). Only one specimen fell below 0.22 and only one was above 0.38.

Taking the normal range of typical *Conus coronatus* as 0.31 to 0.47, and of typical *C. aristophanes* as 0.20 to 0.38 (average ± 2 s. d. units), ratios of 0.31 to 0.38 were common to both species and thus indeterminate. Since this broad indeterminate range covered most of the region between the 2 averages, nearly half of the specimens (42 out of 100) could not be evaluated. Of those shells which could be evaluated, 55 out 57 were properly identified.

Specimens with deeply eroded spires could not have been accurately measured; they were excluded at the onset of the present investigation. And, as in the case of width, relative spire height was often not readily apparent upon simple visual inspection. The use of this criterion also required careful measurements with modified calipers.

4. Spiral Striae

Conus coronatus: 5 or more ridges or grooves per spire whorl.

Conus aristophanes: 3 or fewer ridges or grooves per spire whorl.

Indeterminate: 4 ridges or grooves (7%).

This criterion is similar to the Cernohorsky criterion listed third in Table 1.

Magnification was required to accurately count the number of spiral striae. They were not always distinct or continuous, even along a single whorl, and in many specimens the number of striae varied slightly from whorl to whorl. In examining shells of the present series, the entire spire of each specimen was scanned to find the maximum number of deep striae whether they were on the outermost whorl or on one of the smaller inner ones. Only distinct ridges or grooves were counted so that there would be little question that a shell had at least the number of spiral striae recorded.

In the C-Group, 45 of the specimens were found to have 5, 6 or 7 striations per whorl. Eight was the maximum observed. Two specimens had only 4 striae; none had fewer. On the other hand, 43 of the members of the A-Group had only 2 or 3 striations per whorl. No shell had zero striations; 5 specimens had 4 and one had 5 distinct striae. Four striations were taken as indeterminate.

A simple count of spiral striae had the advantage of being being a reasonably objective process which did not require calipers. By this criterion, 92 of the specimens were identified either as *Conus striatus* or *Conus aristophanes* with but 2 errors (the *Conus aristophanes* mentioned above with 5 striae, and a shell ultimately scored as *Conus aristophanes* which had 6 striae and was mistakenly included in the C-Group).

5. Blotch Color

Conus coronatus: Blotches pure brown with no gray or green.

Conus aristophanes: Blotches gray, olive or green. May have brown or tan undertones, but gray or green predominates.

Indeterminate: Blotches absent or blotches colored other than above; *e. g.*, brown with undertones of gray or green (21%).

While neither the color of the body whorl nor the presence or absence of blotches turned out to be adequately diagnostic in these Fijian specimens, blotch color did. In all specimens of the C-Group, blotches were brown when

present. Shades varied from a delicate and translucent golden to dark and opaque. Occasionally, grayish or greenish undertones were present.

When blotches were present in members of the A-Group, they were nearly always gray or olive. However, the blotches of many specimens in this Group were tinted with brown or tan. The shades of color were subtle and attempting to distinguish between a pure olive-green and a green tinted with brown was not practical. Consequently, a trace of brown was accepted as a standard feature for *Conus aristophanes*.

Several specimens, especially of the C-Group, had blotches which ran together to give an encircling dark band. In such instances the color of the band was taken as the "blotch color." Specimens rich in brown but showing some gray or green were designated indeterminate. Shells without blotches were also designated as indeterminate.

Blotch color proved accurate in 77 of the 78 specimens which could be evaluated by this criterion. However, some care had to be taken in application. Very dark or very light shades of olive sometimes appeared brown upon casual observation. But with a hand-lens, and in good lighting, the green became apparent. Moreover, the green pigment is the first to be lost in sun-bleached shells. This criterion was only applied to fresh specimens with live colors.

6. Pits

Conus coronatus: Rows of pits to shoulder of body whorl.

Conus aristophanes: Pits completely absent.

Indeterminate: Pits present on body whorl but not extending posteriorly as far as shoulder (20%).

As the criterion listed 6th in Table 1, Cernohorsky described the sculpturing of the body whorl of *Conus coronatus* and *C. aristophanes* in terms of interrupted vs. continuous basal ridges. But, in addition to ridges, these shells also were found to have separate and distinct grooves running immediately posterior to the ridges. In the C-Group, these grooves were frequently pitted by small, close-set punctate depressions. In fact, toward the shoulder of most shells in this Group, grooves were absent, and the only sculpturing was parallel spiral rows of tiny but distinct pits.

Many specimens of the A-Group lacked grooves and most lacked pits. When grooves or pits were present in members of this Group, they were generally confined to the anterior half of the body whorl. Only rarely did grooves or pits extend to as far as the shoulder.

The presence or absence of pits could be determined with greater certainty than the presence or absence of grooves, and pits were more diagnostically characteristic than grooves. Hence, the presence or absence of pits (rather than grooves) was taken as the criterion. Of 40 shells pitted all the way to the shoulder, 39 were *Conus coronatus*. And of 40 shells found completely lacking in pits, 39 were *C. aristophanes*. The remaining members of both species were pitted, but the pits did not reach to as far as the shoulder; these were classed as indeterminate.

7. Line Count

Conus coronatus: 17 or more primary lines encircling body whorl.

Conus aristophanes: 14 or fewer primary lines encircling body whorl.

Indeterminate: 15 or 16 lines (45%).

Parallel lines of alternating white and dark brown dots or dashes encircled the body whorl of every specimen. These lines were superimposed on the elevated ridges, when ridges were present. They were immediately anterior, in a one-to-one relationship, to the grooves or rows of pits. Weaker secondary lines, between the main ones and not in proper relationship to the sculpturing, were sometimes seen in large specimens.

In the A-Group the brown of the lines was usually arranged in relatively long and uniform dashes (84%), while in the C-Group the pigmentation tended to be broken into smaller and more irregularly spaced dust-like points (86%). This difference in the nature of the lines was helpful in distinguishing between members of the 2 Groups, but it was not constant enough to serve as a criterion. However, in the C-Group the lines were generally more closely spaced, hence more numerous. Within each Group small shells had as many lines as large ones, and a count of the number of primary lines did provide an acceptable criterion.

Shells in the C-Group averaged 16.7 (s. d.: ± 1.0) primary lines per shell with a range of 14 to 18. In the A-Group the average was 14.8 (s. d.: ± 1.0) with a range of 12 to 17. Setting the indeterminate region at 15 and 16 to cover most of the overlapping zone encompassed nearly half the specimens, but only 2 cases of mistaken identity resulted among the 54 shells which could be evaluated.

Rejected Criteria

Several conchological characteristics were examined and rejected as criteria for distinguishing between shells of the C-Group and A-Group. These were characteristics which were not the near-exclusive property of either Group. Any reliance upon them individually would have

produced an unacceptably high incidence of misidentifications among the specimens under study. Seven of the more visible of these are noted below.

Nature of Coronations (Cernohorsky Criterion Number 4)

While members of the C-Group generally had high and sharply-cut coronations on the spire, and those of the A-Group had lower and more nodulose ones, such was often not the case. In the C-Group, 14% of the shells had low or nodulose (or both) coronations; in the A-Group, 20% had high and sharply-cut ones. In addition, about $\frac{1}{3}$ of the shells in each Group were intermediate and could not be clearly designated as either high or low, sharply-cut or nodulose.

Coronation Count

It appeared that shells of the C-Group had a greater number of tubercles on the spire than those of the A-Group. However, a count of coronated elevations on the body whorls failed to reveal a definable difference between the 2 Groups. Kohn & Riggs (1975) also reported no difference in this parameter among Tahitian specimens of *Conus coronatus* and *C. aristophanes*.

Presence or Absence of Blotch (Cernohorsky Criterion Number 5, in part)

Eighty-two % of the specimens in the C-Group had distinct, dark blotching on the body whorl. In 12% the blotching was diffuse or indistinct, and in the remaining 6% there was no blotch. But many of the A-Group also had blotches. In this Group, 28% were distinctly blotched and another 58% had suggestions of blotches such that they had to be classified as indeterminate. In only 14% were blotches completely and unquestionably absent.

Waist/Shoulder Bands (Cernohorsky Criterion Number 5, in part)

Light colored bands encircling the body whorl at waist and shoulder were features Cernohorsky related to *Conus aristophanes*. And, in fact, 94% of the shells of the A-Group did have such bands. However, so did most of the shells of the C-Group; 52% of the latter had distinct bands, and in another 40% there were hints of bands such that they had to be called indeterminate. Waist/shoulder banding was completely undetectable in only 8% of the members of the C-Group.

Nature of Basal Ridges (Cernohorsky Criterion Number 6)

Most specimens (92%) of the C-Group possessed spiral rows of discrete white beads or granulations over the anterior portion of the body whorl. This produced the strong but interrupted basal ridges of *Conus coronatus* pointed out by Cernohorsky. In fact, in some specimens these rows of granulations covered the entire body whorl. On the other hand, sculpturing in the A-Group was more subdued. Some specimens completely lacked ridges. Others, as per Cernohorsky, had irregular to smooth continuous basal ridges. But many (36%), especially those from the main barrier reef, had distinctly beaded or interrupted ridges. This latter type of sculpturing could not be distinguished from that of typical members of the C-Group.

Body Color – Excluding Blotches

As noted by Cernohorsky (1964), specimens of the A-Group were usually gray or olive-green while those of the C-Group were generally brown, tan or yellow over most of the body whorl. Both were occasionally tinted with pink. The gray/green vs. brown/yellow difference in body color was a good criterion for distinguishing between the 2 Groups. However, when applied to individual specimens, reliance upon color as a criterion, excluding the color of blotches, was singularly misleading. Several shells were misassigned at the onset of the present study when body color was used for preliminary placement into Groups. Specimens of *Conus coronatus* with a pure gray body color were encountered (10% in present series), and a green or olive tint was not uncommon (46%) somewhere on the body whorl of this species. Shells of the A-Group exhibited less variation in body color. Those from muddy inshore locations were generally darker than those from the barrier reef, but in both habitats they were almost always pure gray or olive (96%). Nevertheless, variability within the C-Group precluded using body color as a differentiating character.

White Axial Streaks

Numerous short, irregular, white axial streaks were present in most specimens of the C-Group and in many specimens of the A-Group. They appeared to be more frequent, intense and irregular in the C-Group, but attempts to quantify differences or otherwise define the streaks so as to frame them as a meaningful criterion did not meet with success.

Figure 1

Characteristic shapes of *Conus coronatus* (left) and *Conus aristophanes* (right)

Analysis

Each shell was evaluated on the basis of the 7 Acceptable Criteria described above. Specimens were scored +1 for each *Conus coronatus* character, 0 when indeterminate and −1 for each *C. aristophanes* character. Thus,

Figure 2

Forms of Fijian *Conus coronatus*. Shell at upper left is most typical form

scores ranged from +7 when a shell was evaluated as *C. coronatus* by all criteria, to −7 when evaluated as *C. aristophanes* by all criteria. A plot of this Net Character Score vs. number of specimens resulted in a clearly bimodal distribution with no overlap (see Figure 4). Shells scoring as *C. aristophanes* gave a somewhat lower average and broader distribution because shells in the A-Group more often had to be judged as indeterminate.

Figure 3

Forms of Fijian *Conus aristophanes*. Most common forms at right

Except for truncation at the extreme, distribution within each of the 2 Groups approximated a Gaussian curve. Considering each as such, and considering the Net Character Score as a parametric continuum, normal statistical procedures were applied. Specimens with a positive score averaged +5.7 with a standard deviation of ±1.0. Those scoring negatively averaged −4.9 with a standard deviation of ±1.4. Thus, assuming the 7 criteria to be independent of each other, about 95% of the specimens scoring as *Conus coronatus* were expected to have scores ranging from +4 to +7, and about 95% of the specimens scoring as *C. aristophanes* should have had scores from −2 to −7. Agreement between actual and expected values proved satisfactory.

DISCUSSION

The criteria proposed by Cernohorsky (1964) distinguish between typical Fijian specimens of *Conus coronatus* and *C. aristophanes*. But these 2 species are so closely related to each other, and so variable in form, sculpture and pattern, that one or another of his criteria often fail, or identify a specimen wrongly. To use the Cernohorsky criteria with success, one has to examine a large number of shells to learn which criteria deserve the most credence and which may be disregarded when a specimen has some *C. coronatus* and some *C. aristophanes* characters. From the data presented here, it may be seen that the first 3 of the Cernohorsky criteria listed in Table 1

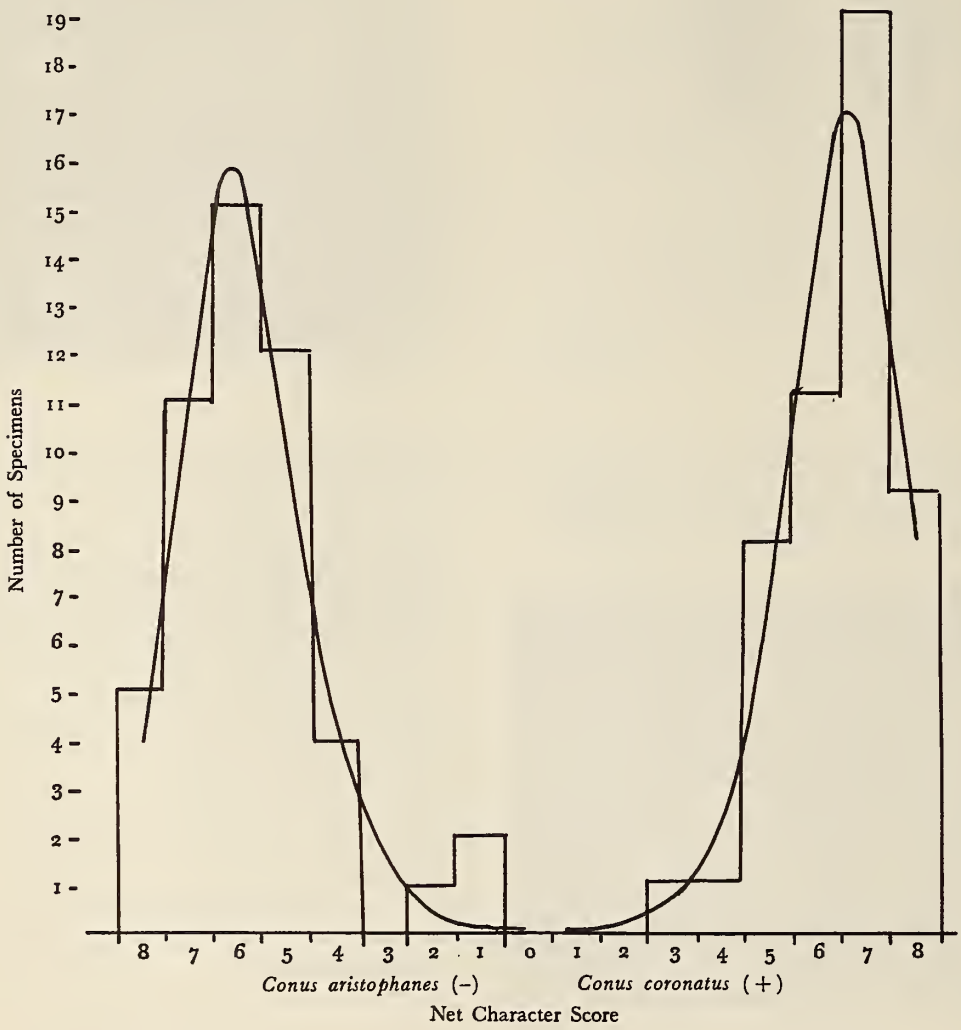

Figure 4

Plot of number of specimens vs. Net Character Score revealing *Conus coronatus* and *Conus aristophanes* as separate population groups. Bar graph shows observed number of specimens plotted against Net Character Scores. Curve shows theoretical distributions within each group as calculated from the 8 individual phenotypic frequencies

are sound ones if interpreted with care, but the last 3 merit little reliance.

In this paper, and in the Cernohorsky publication, the shape of the body whorl is defined descriptively. This provides a rapid and satisfactory means for distinguishing between Fijian forms of *Conus coronatus* and *C. aristophanes,* but a more objective system would be desirable. Kohn & Riggs (1975) have developed a simplified model

for quantifying certain morphometric parameters, and they have applied their methods to specimens of *C. coronatus* and *C. aristophanes* from Tahiti. One of the parameters by which they found the Tahitian species to differ from each other was in "shape of generating curve." This measurement reflects the wide and flaring aperture of *C. coronatus* as compared to *C. aristophanes*. However, other differences in shape (*e.g.*, the more posterior position of the maximum diameter in *C. aristophanes,* the more angular constriction near the anterior tip in *C. coronatus,* etc.) either were not found to differ or were not evaluated by the Kohn and Riggs model. Such differences are slight, and they will probably be difficult to quantify with sufficient sensitivity, but the eye can usually discern them in Fijian specimens.

Relative width was not mentioned by Cernohorsky, but it was one of the morphometric parameters which Kohn and Riggs found to differ in Tahitian specimens. As "relative diameter," they found *Conus coronatus* and *C. aristophanes* to average 0.75 and 0.71, respectively. Aside from the possibility that Tahitian and Fijian specimens might differ, these values are lower and not as widely separated as reported in the present study because of a slight difference in the method of calculation. As denominator, Kohn and Riggs took the entire body whorl ("aperture height"), which includes both the lateral and posterior aspects of the final whorl. Here, the body whorl is measured only to the external shoulder with the posterior portion of the last whorl being considered as spire. Since the spire of these 2 species does differ (*C. coronatus* is high, *C. aristophanes* is low), including the posterior aspect of the last whorl in the denominator decreases the width to height ratio by only a little in the case of *C. aristophanes,* but by more in *C. coronatus.*

For comparative purposes, the relative widths of the Fijian specimens studied here may be calculated in 3 ways: 1. Denominator equal to body whorl to shoulder (as in this study); 2. Denominator equal to entire body whorl (as per Kohn and Riggs); 3. Denominator equal to total shell length. Respective values, with those of *Conus coronatus* given first, are: 1. 0.90 ± 0.03 vs. 0.82 ± 0.02; 2. 0.82 ± 0.03 vs. 0.77 ± 0.02; 3. 0.65 ± 0.02 vs. 0.63 ± 0.03. As may be seen, differences between the 2 species become less as more spire is included in the denominator until including all of the spire negates the usefulness of relative width as a meaningful parameter. From the second set of values, it appears that Fijian specimens are somewhat broader than their Tahitian counterparts.

Spire height is a sound criterion when carefully quantified. Cernohorsky simply stated that *Conus coronatus* has a higher spire than *C. aristophanes,* and this is generally true; but, without actual morphometry, this is often not a criterion which can be applied with any degree of confidence. As far as Fijian specimens are concerned, relative spire height can only be used as a criterion for distinguishing between these 2 variable species when measurement shows it to be equal to or greater than the average for *C. coronatus,* or equal to or less than the average for *C. aristophanes.*

Kohn & Riggs did not measure relative spire height, *per se.* One of their parameters, "relative whorl height" (height of the penultimate whorl/aperture height), might correlate with the relative spire heights recorded here, but their measurements revealed no difference between Tahitian specimens of *Conus coronatus* and *C. aristophanes.*

The number of spiral striae is also a sound criterion when properly quantified, but Cernohorsky did not tell one what to do when there were 3 or 4 striae. The data presented herein alleviate this problem with respect to Fijian specimens. Kohn and Riggs used the number of spiral striae as a single criterion for specifying a shell as *Conus coronatus* ($\geqslant 5$) or *C. aristophanes* (< 5), hence a difference in their values for this parameter was predetermined. In their Tahitian material they found the former averaged 5.8 striae and the latter 2.9 striae per whorl. The Fijian specimens of the present study averaged 6.0 and 2.9 striae per whorl, respectively.

Blotch color, the presence or absence of pits, and line count are criteria not addressed by either Cernohorsky or Kohn and Riggs. Cernohorsky did mention that the blotches were brown in *Conus coronatus,* and this is in agreement with the findings of the present study, but he did not specify blotches in *C. aristophanes.* Each of these 3 criteria appears to be as accurate and reliable as any other for distinguishing between Fijian specimens of *C. coronatus* and *C. aristophanes.*

All 7 acceptable criteria have an accuracy of at least 95%. Thus, all are considered equally credible. But, since none is 100% reliable, it is inevitable that an occasional specimen will have one or more characters of the wrong species. The question which arises is: How should specimens with mixed results be considered?

A shell with one *Conus coronatus* character, one *C. aristophanes* character and 5 indeterminate evaluations cannot be identified as either species because neither character may be disregarded in favor of the other. On the basis of the given criteria, it can not be separated from a shell with 7 indeterminate evaluations. Any shell with an equal number of *C. coronatus* and *C. aristophanes* characters can no more be designated as one species or

the other than a shell with 7 indeterminate evaluations.

To accommodate this situation, and give equal weight to all criteria when scoring a shell, the number of *Conus aristophanes* characters is simply subtracted from the number of *C. coronatus* characters. This results in a Net Character Score for each specimen with typical *C. coronatus* scoring positively and typical *C. aristophanes* scoring negatively. This procedure also establishes a scale, ranging from +7 to −7, which facilitates graphic display of data (Figure 4) and permits a parametric type of analysis on the overall results.

It must be noted that the Net Character Score derived in this way does not unequivocally identify a specimen. On rare occasion a *Conus aristophanes* may be scored as a *C. coronatus,* or vice versa. Rather, it gives a tentative identification to specimens with those furthest removed from zero being the ones most convincingly documented.

There are two essential assumptions inherent in this model for discriminate analysis. First, it is assumed that the observed phenotypic characters are independent of each other. Second, it is assumed that there are two, and only two, species present in this *Conus*-complex.

Data are very limited, but it would appear that the first assumption is probably valid. As may be seen from Table 2, out of the total of 693 evaluations, there are only 14 instances of mistaken identity. The 8 in the A-Group are spread over all 7 criteria, and the 6 in the C-Group are spread over 5 criteria. Such scatter seems random. However, the data are far too few to document independence of these characters within either Group. The acceptable criteria are diverse in type: 3 are morphological, 2 reflect sculpture, and 2 are based on pigmentation or pattern. Until more data are available, it would not seem unreasonable to continue to assume such characters are independent.

From the data, as presented in Figure 4, the second assumption has also not been discredited. No third peak is seen. If there is a third species present, it must either be occurring at low frequency, or the criteria are inadequate to separate it from one of the two recognized species. Additionally, if hybridization is occurring, it must also be at low frequency. One would expect hybrids to score intermediate between the two species, but there is no obvious cluster of specimens scoring in the neighborhood of zero.

Finally, habitat can also influence form, sculpture, pattern and color. This is particularly true in the case of *Conus aristophanes*. This species can inhabit any environment from inshore mudflats to the outer barrier reef. Specimens from the barrier reef more closely resemble *C. coronatus*. They are generally a lighter shade of gray or green, more heavily granulated, slightly broader and slightly higher in the spire than specimens from inshore muddy areas. Nevertheless, specimens from both habitats score well to the negative side of zero by the Net Character Score.

CONCLUSION

The shells of 50 specimens of *Conus coronatus* and 50 specimens of *C. aristophanes* collected in Fiji have been examined for differences in form, sculpture, color and pattern. Seven criteria which distinguish between these two closely related species have been isolated. Each is greater than 95% accurate. Considered together, these criteria permit identification of individual Fijian specimens of *C. coronatus* or *C. aristophanes* with a high degree of certainty. They separate Fijian specimens into two distinct and non-overlapping population groups, thereby providing evidence in support of the Cernohorsky (1964) conclusion that *C. coronatus* and *C. aristophanes* are distinct and separate species.

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